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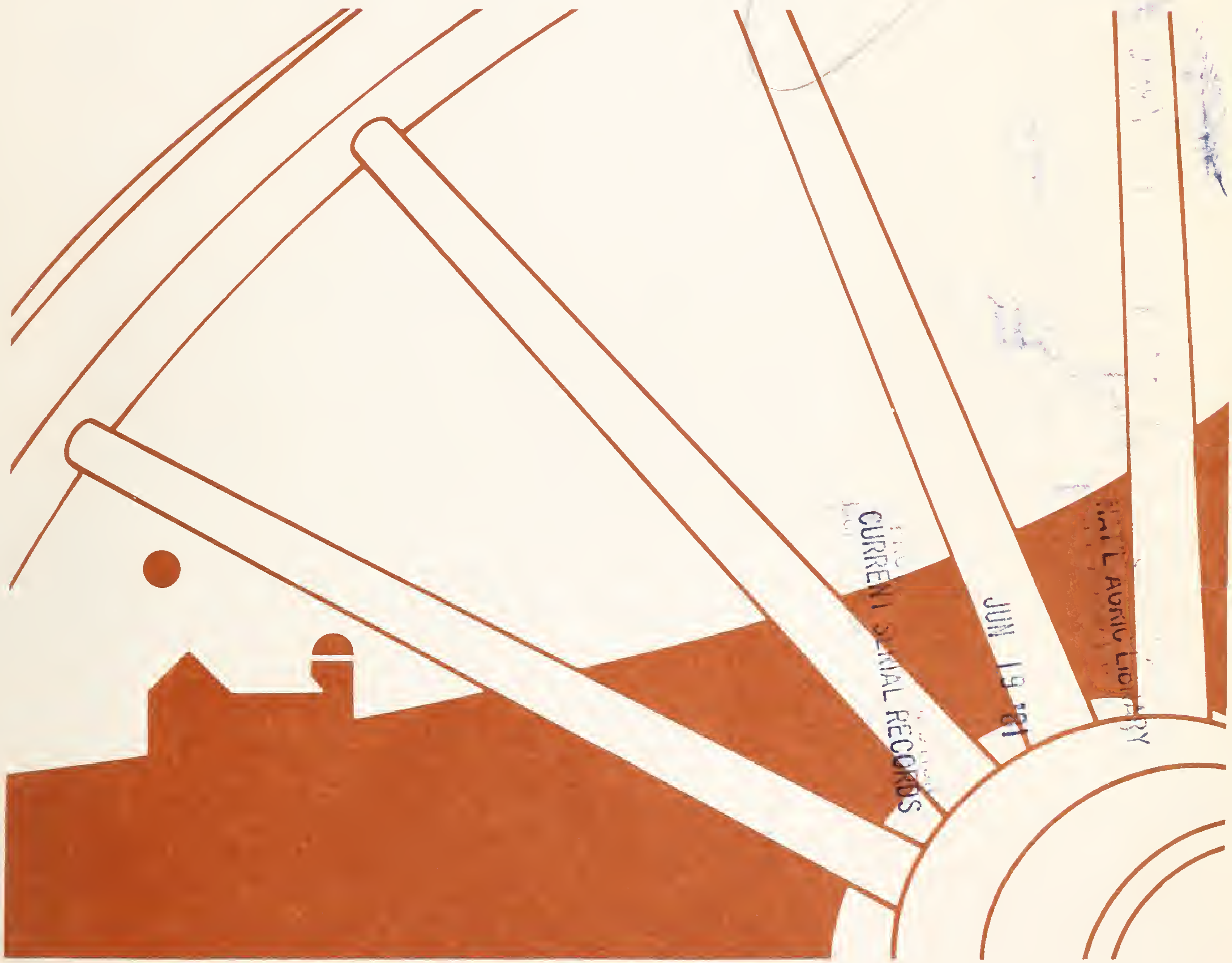
A Bibliography for Small and Organic Farmers 1920-78



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A BIBLIOGRAPHY FOR SMALL AND ORGANIC FARMERS
1920-78

By J. W. Schwartz[1/]

INTRODUCTION

Small farmers and organic farmers have expressed a need for assistance in developing alternatives to today's highly intensive and mechanized farming practices. Generally, this involves reducing or excluding the use of chemical fertilizers and pesticides and relying instead on untreated minerals, crop rotations, mulches, legumes, animal and municipal wastes, and green manures to supply nutrients and control weeds.

The bibliography presented here consists of 1,176 publications of long-term research by scientists of the Science and Education Administration-Agricultural Research's Soil, Water, and Air Sciences staff (SWAS) from 1920 to 1978 that relate to the needs of both the small and organic farmers. Only those publications that were considered most useful to these groups of farmers were selected. They are listed under 19 subject areas according to the year published. A brief summary of the subject area appears at the beginning of each section.

The publications listed can be obtained from most State university libraries or from the Technical Information Systems of the U.S. Department of Agriculture.

[1/] Soil scientist, Science and Education Administration, Soil, Water, and Air Sciences.

Animal Wastes

Animal wastes applied to farmland supply plant nutrients and may improve the physical structure of soils. Their effective use, however, requires a high level of management. When using animal waste in the form of manure, one should be aware that (1) the nutrient content of manure is highly variable and excessive applications may result in nitrate leaching, (2) up to 50 percent of the total nitrogen in manure may be lost within 1 week if stored improperly, and (3) manure improperly spread on the soil surface can pollute surrounding areas via runoff water. Other areas of concern in use of animal wastes on farmland are accumulations of salt in the soil, unpleasant odors, metal toxicities, and pathogen hazards.

Approximately 2 billion tons of animal wastes (wet weight) are produced each year in the United States. The most practical means of disposing of these wastes is as fertilizer in the form of manure. Manure, however, cannot substantially replace chemical fertilizer for several reasons: (1) A large part of this waste is already being used in conjunction with chemical fertilizers; (2) approximately 50 percent of the waste is not collectible; (3) this waste contains onlv 1 to 2 percent nitrogen; (4) 50 percent of the nitrogen in the waste is lost by leaching, erosion, or volatilization, or all of these, before being utilized by a crop; and (5) only 50 percent of the nitrogen in manure is available for crop use the first year after application.

Currentlv, commercial fertilizer is the major source of nitrogen, supplying over 9 million tons. Manure, on the other hand, furnishes about 1.2 million tons of nitrogen and legumes, about 2 million tons. Manure should not be viewed as a substitute for commercial fertilizers, but as a valuable additive that can improve soil structure and supply small amounts of nutrients. Additionally, its application to land solves a waste-disposal problem.

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Conservation Tillage

The objective of conservation tillage is to reduce soil manipulations to the minimum that is biologically, technologically, and economically feasible. Often the determining factor for adopting conservation tillage is costs of tillage operations to control weeds versus costs of alternatives such as herbicides, mulches, flame, and oil sprays.

Conservation tillage requires a higher level of expertise in soil and crop management than is needed for conventional methods. Two serious problems in crop management are control of weeds and insects. Other problems are slow spring warmup of some soils, restricted placement of fertilizer and lime interference of residue with mechanical operations, and reduced seed germination due to toxic substances in the residue.

Compliance with water and air pollution standards or regulations could become an important factor in future reductions in tillage. Specifically, two laws may necessitate conservation tillage on a substantial part of cropland: The Federal Pollution Control Act Amendments of 1972 (PL 92-500) and The Clean Air Act as amended in 1970 (PL 91-604). Water and wind erosion can be substantially reduced by using conservation tillage practices. The degree of effectiveness of a particular system or machine depends on the surface conditions induced. The effectiveness is directly related to the amount of residues left on the surface, amount of residue mixed into the upper few inches of topsoil, surface roughness, and ridges or residue strips on the contour. It is inversely related to the amount of soil pulverization. A reduction of 50 percent or more in soil erosion by the year 2000 could be the principal public benefit of minimum tillage.

A technological assessment of conservation tillage was conducted in 1975 by the U.S. Department of Agriculture. The assessment concluded that:

-- Corn, sorghum, soybeans, and small grains are the major crops minimum tilled and with potential for expansion in minimum tillage.

-- More than 80 percent of the acreages of all crops could be minimum tilled by the year 2000; nearly half of all crop acreage could be no-tilled by that time.

-- Harvested acreage annually could be increased by 20 million acres by the year 2000 because of reduced tillage; about 15 million of these acres would be gained by multicropping. Total farm output could increase about 5 percent because of this increased harvested acreage.

-- Prospects of significant savings in production costs (especially labor) appear to be the principal reason for farmers to adopt reduced tillage practices. Nationally, savings to farmers could approach $1.6 billion annually by the year 2000.

-- Savings in energy costs for operating farm machinery (about $275 million annually) were offset by an estimated increase of $300 million in added cost of pesticides to farmers in the year 2000.

-- Reduction requirements for farm labor could be as high as 350,000 worker-years by the year 2000 (mainly in family labor, rather than hired labor), permitting increased off-farm employment or increased leisure time for members of farm families.

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Crop Residues

Residues remaining on or in the soil are a valuable source of organic matter and nutrients and are important in controlling wind and water erosion and improving soil tilth. Traditionally, residues are plowed under to hasten decomposition, to keep them from interfering with subsequent tillage, and to control insects and diseases.

Recently, crop residues have been viewed as a potential source of energy. They can be converted into energy by fermentation (for example, methane gas), by pyrolysis, or by direct combustion. About 330 million tons of crop residues (such as cornstalks, wheat, and straw) are produced annually by the nine leading crops in the United States. Currently, most crop residues are left in the field and returned to the soil. Scientists have estimated that if all crop residues were used as an energy source, they could supply 2 percent of the current U.S. energy demand.

The Nation's commercial fertilizer needs would be increased greatly if all residues were removed from the land. For example, the residue from a 150-bushel-per-acre corn crop contains about 93 pounds of nitrogen, 15 pounds of phosphorus, and 112 pounds of potassium.

Conservation and no-till practices that leave residues on the land commonly reduce the average erosion rate by at least half. The amount of residues needed to control erosion depends on soil type, topographic conditions, and the weather. In some areas, all available residues are needed on the land; in others, some could be removed for other purposes.

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Crop Rotation

Legumes and legume-grass mixtures traditionally have been included in crop rotations primarily because their growth does not depend on nitrogen in the soil. When properly inoculated, legumes make excellent growth and not only supplv nitrogen to the following crop but also provide forage for livestock. Many legumes with deep root systems are also considerably beneficial in opening up impermeable soils.

With abundant and inexpensive supplies of commercial fertilizers available during the last two or three decades, however, farmers found it less costly to apply commercial fertilizers to the soil for nitrogen than to grow legumes. In fact, the availability of abundant commercial nitrogen greatly reduced the need for any rotation of crops except on certain problem soils or where disease was a major factor. Corn, for example, when heavily fertilized, produces such an abundant supply of roots and residue year after year that the residual effect on the soil is usually as satisfactory as in a rotation that includes legumes. With recent increases in the cost of commercial nitrogen fertilizers, however, there may be merit for farmers to consider again using legumes as part of their crop-management scheme.

The amount of nitrogen a legume adds to the soil depends on the plant species and how it is managed. Soybeans are a legume, but most of the nitrogen they can fix is removed as protein in the harvested beans. Alfalfa, sweet-clover, red clover, and ladino clover are among the more effective legumes for building up soil nitrogen. As a general rule, the more top growth turned under when a legume field is plowed, the more nitrogen added to the soil. A perennial such as alfalfa likely will add 100 pounds of nitrogen per acre to the soil.

Various crops affect the soil supply of mineral nutrients in the soil differently. Some crops can extract nutrients from the soil more effectively than others. When these strong feeders are grown in a rotation, turned under, and decomposed, the minerals they absorbed are converted to readily available forms for the following crops. For example, sweetclover absorbs phosphorus from rock phosphate more readily than does corn or wheat. Buckwheat can also utilize less available forms of some mineral nutrients that can in turn be utilized by the subsequent crop.

Crop rotations can also decrease weed, insect, and disease problems. A 3-year rotation of corn, oats, red clover, and timothy sod was once very popular in the Corn Belt. Cotton, wheat, lespedeza, corn, cotton, and oats followed by one or more years of fescue clover have been commonly used in the South. Potatoes with redtop or a 3-year rotation of potatoes, oats, and red clover were used in New England. Rotations of sugarbeets, field beans, potatoes, and barley with several years of alfalfa were common on irrigated land of the West.

Crop rotations that include a legume or legume-grass sod can reduce wind and water erosion, increase soil organic matter, supply nitrogen and other nutrients for subsequent crops, improve soil structure, and in some cases decrease weeds, insects, and diseases. Where costs for land and labor are low and the cost of commercial nitrogen is high, a crop-rotation system that uses a legume may be one way farmers can increase their profits.

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Double Cropping

In areas that have a long growing season, such as the Southeastern United States, double cropping can increase yields, reduce erosion, and control some weeds, insects, and diseases. Examples of double cropping are corn and grain sorghum in Georgia, soybeans and wheat or wheat and grain sorghum in Mississippi, and corn and grass species in West Virginia.

Since double cropping keeps vegetative cover on the soil between crop rows, erosion is reduced. However, the additional vegetation may deplete the soil moisture and irrigation may be required. Also, without conventional cultivation of row crops, weeds such as nutsedge can be a problem.

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Drip Irrigation

Drip or trickle irrigation is the application of small, controlled amounts of water through small plastic tubes that have emitters or drippers located near each plant. Thus, water is saved because the area between plants is not wetted.

Drip irrigation originated in Germany in the 1960's when clay pipes with open joints were laid below the soil surface in an effort to combine drainage and irrigation in one system. In 1930, a system was devised in Australia using galvanized pipes with small holes cut along its length, and in 1948 a similar system was tried in the United Kingdom. Drip irrigation appeared in the United States in the early 1960's and has been widely adopted in areas where there are water shortages and rising costs for labor, power, and water. Because of its high installation costs, it is most economical for use on vegetable crops and orchards.

Persistent problems with drip irrigation are sediment plugging the emitters, deposition of dissolved iron and/or calcium, and a buildup of bacteria. Researchers are working to solve these problems by such methods as use of filters to reduce sediment and sulphuric acid or chlorine to prevent bacterial growth and deposition of dissolved calcium.

Drip irrigation has several advantages, such as reduced water use; decreased spread of water-borne disease; and more efficient application of nutrients, growth hormones, minor elements, insecticides, and herbicides.

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Earthworms

Earthworms can influence the physical structure of a soil by their activity and castings; however, they have little or no effect on the fertility of soil. They grow best in well-drained soils that contain abundant organic matter and a continuous supply of calcium. The organic residues ejected by earthworms are lower in nutrients than the residues ingested. The beneficial effects of earthworms on plant growth are largely those associated with improved aeration and tilth. The presence of abundant earthworm populations is an indication of good soil fertility rather than its cause. Fertilization and management practices that increase plant growth usually increase earthworm populations because the larger amount of crop residue provides more food and shelter for the worms.

Anyone interested in raising earthworms should first ensure that he or she has a market before attempting their commercial production. There is no general market for earthworms for agricultural purposes because: (1) Earthworms are already widely distributed; (2) if soil conditions are unfavorable for earthworms, the addition of earthworms is of little value because they will not survive; (3) the number of earthworms required to affect soil appreciably--a half million or more per acre--cannot be supplied economically by transplanting; and (4) varieties of earthworms adapted to rapid production in commercial beds do not long survive under field or garden conditions. There is a small market for earthworms as a fish bait and, occasionally, for use by zoological parks and educational institutions.

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Green Manure

A green manure crop is one that is grown and plowed under to improve the soil. This practice dates back to the beginning of a settled type of agriculture where crops were grown more or less continuously on the same areas. In China, green crops, mostly legumes, were grown and plowed under directly or as a compost for manuring rice field more than 3,000 years ago. In Greece and Rome before the time of Christ, green manuring was a fairly common practice. Lupines, beans, clovers, and other legumes were grown on the poorer soils and incorporated into the soil while green.

Green manure crops are usually annuals, either legumes or grasses. They can add nitrogen to the soil, increase the general level of fertility, supply organic matter, reduce erosion losses, improve the physical condition of the soil, and reduce leaching of nutrients. Green manures can also cause problems, such as increased incidence of diseases; increased populations of insects and nematodes; deplete soil moisture; and have adverse effects on the stand of the next crop because of toxic material in the residue. The desirability of green manuring, therefore, depends on the soil, climate, and the crop.

Of the various green manure crops tested in the Southeastern United States, legumes were superior to nonlegumes and winter legumes were superior to summer legumes. Hairy vetch was the most dependable green manure crop.

The effects of green manures are generally beneficial, and fortunately most of the harmful effects can be avoided by following good management practices. The determining factor for growing a green manure crop is likely to be economics. The greatest need for green manure crops is in the warmer climates, where high biological activity rapidly depletes reserves of soil organic matter.

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Inorganic and Organic Fertilizers

Supplemental plant nutrients 30 years ago consisted mainly of products like dried blood, tankage, bonemeal, and animal manures. The first chemical fertilizer used in the United States consisted of guano (bird manure) and potash salts. It was made in Baltimore, MD., in 1850. Today, fertilizer manufacturing is the largest heavy chemical industry in the world.

Nutrients can be supplied from either organic or inorganic sources. Regardless of the source, the material must break down into its ionic form before the plant can absorb it. The ions absorbed by the plant are identical whether they are derived from an organic or an inorganic source. Therefore, in nutritional benefits to plants, when similar quantities of nutrients are used, neither organic nor inorganic fertilizers is more advantageous. The following table lists some common inorganic fertilizers.

		Analysis		
Inorganic fertilizer	Formula	Nitrogen	Phosphoric pentoxide	Potassium oxide
Sodium nitrate	$NaNO_3$	16	0	0
A.N.L., or Cal-Nitro	NH_4NO_3 + dolomite	20	0	0
Ammonium nitrate	NH_4NO_3	30	0	0
Urea	$CO\ (NH_2)_2$	42	0	0
Superphosphate	H_3PO_4&$H_4P_2O_7$	0	46	0
Rock phosphate	Fluor-&chlorapatites	0	25	0
Complete fertilizer		5	10	5
Complete fertilizer		5	10	10
Complete fertilizer		10	10	10

Most chemical fertilizers become available for plants rapidly when added to the soil. As they are caustic, they may burn the plants if overapplied.

Organic fertilizers are more expensive than inorganic types. They are less caustic, however, and will cause less burning of plants if used in large applications. The organic materials are more slowly available to plants, which may be an advantage in some situations. The following table lists materials that can be used as an organic fertilizer.

	Analysis		
Organic fertilizer	Nitrogen	Phosphoric pentoxide	Potassium oxide
Alfalfa hay	2.45	0.50	2.10
Bat guano	1 to 12	22.5 to 16	0
Blood meal or dried blood	10	1	0
Bonemeal (steamed or raw) $(Ca_3PO_4)_2$	2	25	0
Ground bone, burned	0	34.70	0
Coffee grounds	2.08	.32	.28
Corncobs (ground, charred)	0	0	2.01
Cottonseed or linseed meal	7	2	1
Dog manure	1.97	9.95	.30
Eggshells	1.19	.38	.14
Fish scrap (fresh)	2 to 7.5	1.5 to 6	0
Fresh-water mud	1.37	.26	.22
Greensand	0	1 to 2	5.00
Hair	12 to 16	0	0
Manure (cattle or horse)	1	.5	1
Manure (poultry)	1.0	.8	.4
Manure, dry (cow or sheep)	1	1	1
Manure, goat	1	1	2
Oak leaves	.80	.35	.15

Organic fertilizer	Analysis		
	Nitrogen	Phosphoric pentoxide	Potassium oxide
Peanut shells	.80	.15	.50
Pigeon manure (fresh)	4.19	2.24	1.41
Pine needles	.46	.12	.03
Seaweed (Atlantic City, N.J.)	1.68	.75	4.93
Sludge (activated sewage)	5	3	0
Soot from chimney flues	.5 to 11	1.05	.35
Tankage	5 to 10	10 to 20	0
Timothy hay	1.25	.55	1.00
Tomatoes, leaves	.35	.10	.40
Tomatoes, stalks	.35	.10	.50
Waste from hares and rabbits	7.00	1.7 to 3.1	.60
Wood ash	0	0	4 to 6
Wood ash (unleached)	0	1 to 2	4 to 10

Inorganic fertilizers such as sodium nitrate, ammonium nitrate, urea, and complete fertilizer (such as 10-10-10) will cost about $0.15 to $0.20 per pound of nutrients. Organic fertilizers such as blood meal, bonemeal, cottonseed or linseed meal, tankage, manure and sludge are more expensive and will cost from $2 to $3 per pound of nutrients.

Although dried blood, bonemeal, cottonseed or linseed meal, and tankage have a relatively high nitrogen content, they are more useful and valuable as livestock feed than as fertilizer. From a practical conservation point of view, these waste products should be recycled as feed and the resulting manure then used as fertilizer.

Use of fertilizers is just one set of practices that contribute to the abundance and variety of our food supply. There is no evidence from public health statistics or research that the variety and abundance of food in this Nation have been obtained at a sacrifice in the concentration of essential nutrients in the food crops produced. Fertilizers have been an essential part of a complex set of agricultural practices that have permitted people in the developed countries to exchange the nutritional problems of the hungry for the nutritional problems of the overfed.

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Legumes

Farmers in the past depended largely on legumes and animal manure as sources of nitrogen for their crops. In recent years, however, they have turned more and more to synthetic ammonia to meet crop needs. This change is largely a matter of economics, which in turn is influenced by the type of farming and the use to be made of the legume. For example, in livestock farming, legumes are especially valuable as feed and as suppliers of nitrogen. But in grain farming where their feed value is not realized, legumes may be a more expensive source of nitrogen than commercial fertilizer.

The air over every acre of the land area has been calculated to contain about 34,500 tons of nitrogen. This inexhaustible supply remains constant, because nitrogen is being returned to the atmosphere at about the same rate as it is being removed.

Higher green plants cannot utilize gaseous nitrogen directly. It must first be combined with other elements. The process of producing such combinations is called nitrogen fixation. Such combinations are brought about in several ways, chiefly by electrical discharges in the atmosphere, by various reactions in industrial processes, and by several species of micro-organisms living in the soil, plant tissues, and fresh and salt waters.

Nitrogen fixed by lightning combines with the oxygen of the air to form nitrogen oxides. These oxides are washed out of the air by rain or snow and reach the soil in the forms of nitrous and nitric acids. The total amount of nitrogen brought down by rains annually varies with the rainfall, frequency of electrical storms, and nearness to industrial areas where ammonia is being

released. The average figure for cropped areas in the humid-temperature region is about 5 pounds of combined nitrogen an acre per year. Two-thirds or more of this is not newly fixed nitrogen but is combined nitrogen, chiefly ammonia that escaped from the soil or was released as a result of burning coal and other materials. A small percentage consists of micro-organisms and other forms of organic matter carried into the air by wind.

Legumes may fix up to 200 pounds of nitrogen an acre each year if effective strains of the proper root nodule bacteria are present in the soil or are added to the seed as commercial inoculants. These bacteria penetrate the root hairs, live in the root nodules formed, and in cooperation with the higher plant take nitrogen from the air for the use of both the bacteria and the crop. An average fixation value is usually 50 to 100 pounds, depending on the kind of legume. When available soil nitrogen is abundant, legumes are likely to use it in preference to atmospheric nitrogen. The amount of nitrogen fixed in nitrogen-deficient soils parallels closely the amount of carbohydrate photosynthesized by the plant and plant dry weight.

Bacteria are the chief free-living micro-organisms that fix nitrogen. A few fungi and yeasts also can do so. A few genera of blue-green algae, often observed as a green scum on ponds, also can use atmospheric nitrogen and are of economic importance where paddy rice is grown. We do not know exactly how much nitrogen is fixed by nonsymbiotic (free-living) soil organisms, such as azotobacter and clostridia. J. G. Lipman and A. B. Conybeare of the New Jersey Agricultural Experiment Station estimated it to average 6 pounds per cultivated acre a year in the United States.

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Limestone

The use of lime to correct soil acidity is an essential management tool to ensure maximum crop yields.

Lime corrects soil acidity, supplies calcium, improves the availability of some other plant nutrients, and increases the efficiency of fertilizers and manures. It promotes desirable biological activity and improves the structure of certain acid soils. Most soils in humid regions require periodic liming to maintain a proper soil pH.

Record shows that liming was practiced in some countries before the Christian era. In colonial times a few farmers limed their soil. During the 19th century the practice became extensive in some localities in the United States, but, except in Pennsylvania, never became general or permanent. At that time farmers had scant knowledge of the need for liming. Moreoever, liming materials were often costly and scarce.

The most commonly used material to correct soil acidity is finely ground calcic limestone. Where magnesium is also required, dolomitic limestone is used. Other common forms of liming material are burned lime, slaked lime, marl, industrial lime wastes, wood ash, and ground or burned mollusk shells.

The type of liming material an individual chooses is determined by the need for magnesium, availability, cost, rate of reaction with soil, and ease of handling and storing.

The capacity of a liming material to correct acidity is determined by its neutralizing value or power. Pure calcium carbonate has a neutralizing power of 100; other liming material are compared on a percentage basis with pure calcium

carbonate. Because of impurities and other forms of carbonates in liming materials, the neutralizing power of commercial products can range from 50 to 200 percent. Most high-calcium limestones have a neutralizing power between 75 and 95 percent. When a material contains appreciable amounts of magnesium carbonate, calcium hydroxide, calcium oxide, or magnesium oxide, the neutralizing power will be greater than 100 percent.

Farmers generally apply 1 to 6 tons of lime per acre of soil, depending on the crop and type of soil. The only way to determine the need for lime is to have the soil analyzed. Soil-testing laboratories are operated in almost every State through the agricultural experiment stations and extension services. Soil-testing services are also available from many private companies and consulting services.

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Micronutrients

Plants require 17 elements for normal growth and reproduction. Iron, manganese, copper, zinc, boron, molybdenum, and chlorine are required in very small quantities, and thus are known as micronutrients.

Interest in micronutrients has increased in the last two decades because (1) crop removal of trace elements has sometimes lowered the concentrations in the soil to the point where normal plant growth is not possible; (2) high-analysis fertilizers do not contain micronutrients as an impurity; (3) better diagnostic tools are available for determining micronutrient status; and (4) high levels of micronutrients in the food chain pose a hazard to humans and animals.

The importance of micronutrients for the health of humans and animals cannot be overemphasized. Some examples of cause-and-effect are iodine deficiencies and goiter, fluorine deficiency and bad teeth, zinc deficiency and dwarfism, and cobalt deficiency and unthrifty livestock.

Whether a particular micronutrient contained in soil is available for plant growth depends on soil texture, soil organic matter content, and soil pH. For example, the availability of copper, zinc, boron, manganese, and iron is relatively high at pH 6.5 or below but decreases rapidly above pH 7.0.

High levels of micronutrients also occur and can restrict plant growth or accumulate in plant tissue or both of these, creating a threat to the food chain. Toxic levels of micronutrients may result from natural soil material containing high concentrations of micronutrients like some animal or municipal waste and agricultural chemicals. Micronutrients should not be applied to cropland unless a need has been established by soil tests, plant analysis, and plant deficiency symptoms.

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Mulching

Use of mulches is an old practice, possibly dating back to the beginning of agriculture. Among the materials commonly used for mulching are crop residues, sawdust, woodchips, and manure. Paper, plastic, or even stones are sometimes used. If large amounts of material such as straw, tree leaves, woodchips, or sawdust are used as a mulch and incorporated in the soil, plants may develop nitrogen deficiency because of vast numbers of micro-organisms that tie up the nitrogen in their body proteins. Additions of nitrogen fertilizer, however, will alleviate this problem.

Composted organic matter is often used as a mulch. The organic matter used for composting should contain about 10 parts of carbon for each part of nitrogen, or a carbon to nitrogen (C/N) ratio of 10. Sawdust, leaves, and straw have a C/N ratio of 30 or higher. Plants mulched or fertilized with this material may suffer from nitrogen and phosphorus deficiency. When preparing a compost with organic matter that has a C/N ratio of 30 or more, adding 1 to 2 cups of 10-6-4 or similar fertilizer for each tightly packed bushel of material will alleviate this problem.

Costs and limited supplies of commercial mulching materials have restricted the use of applied mulching largely to the production of relatively high-value crops, to special uses, or to circumstances in which the need for mulching to conserve moisture or prevent erosion is acute.

Among the more important ways in which mulches may affect soil conditions are by (1) maintaining soil structure, (2) conserving moisture, (3) modifying temperature, (4) increasing the availability of plant nutrients, and (5) reducing soil erosion.

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Nutrition

Many food crops produced in the United States are grown on soils that have been used for farming for many years. Some researchers are concerned that these soils have become so depleted of nutrients that the nutritional quality of the food crops produced on them has declined. Some of this concern stems from the belief that the common types of fertilizers used meet only the crop requirements for the major elements, such as nitrogen, phosphorus, and potassium, and permit soil reserves of the trace elements to decline to levels that may jeopardize the nutritional quality of crops. At the same time, others have maintained, on the basis of improved public health statistics, that the nutritional quality of today's crops is higher than that of crops of early periods. This controversy must be examined in terms of specific nutrients and specific crop-production and soil-management systems.

Cropping soils for many years does not automatically cause depletion of soil nutrients. Many soils have been improved in their nutrient supply through use of modern farming practices. When some of the sandy soils of the U.S. eastern seaboard were cultivated by the colonists, the first crops suffered from many nutrient deficiencies and westward movement to find better soils was taking place before the Revolution. Some of these fields have since been built up from continued use of fertilizers, lime, animal manure, and green-manure crops until now they are among the most productive vegetable crop soils of the world. Similar instances of soil improvement during long periods of agricultural use are found in Western Europe.

Some of the most dramatic cases of nutritional deficiencies in humans or animals that trace to a mineral deficiency in certain soils are due to naturally occurring deficiencies rather than those due to soil depletion by cropping. Shakespeare wrote of a high incidence of goiter in mountainous regions now known to be deficient in iodine. The cattle of the early colonists of the Sacco Valley of New Hampshire suffered from a "wasting disease," which was attributed to a curse placed on the valley by the Indian Chief Chocorua. The "curse of Chocorua" is now known to be due to cobalt deficiency. When the Columbia Basin of the Northwestern United States was first used for irrigation agriculture, zinc deficiency was so severe that corn and bean crops failed on many farms. These naturally occurring deficiencies and many similar ones have since been corrected by use of iodized salt, trace element fertilizers, and mineral supplementation of animal diets.

There is widespread concern today about the effect of inorganic or chemical fertilizer on the nutritional status of food crops as compared with so-called natural organic fertilizers. However, results of experiments conducted to compare the levels of different essential nutrients in crops grown with organic fertilizers against those grown with comparable amounts of nutrients supplied as inorganic materials have shown only small differences, with the advantages favoring the inorganic as often as the organic forms.

These results are as expected because the function of plants in the food chain is to convert inorganic compounds to organic compounds. If organic materials containing essential elements are incorporated into soil, the micro-organisms in the soil break down the organic matter into inorganic forms.

Inorganic ions of the essential nutrients are then taken up by plant roots and synthesized into new organic materials within the plant. In the plant, and in the body of the human or animal that eats the plant, these essential nutrient elements have the same effect regardless of whether they were added to the soil as organic fertilizers or as inorganic chemical fertilizers. No laboratory test or animal feeding trial can distinguish crops grown with inorganic fertilizers from those grown with organic fertilizers.

The food-production systems of the future will almost certainly include a combination of organic and inorganic fertilizers. The exact nature of this combination will vary from different farms and for different countries depending on their access to fossil fuels, their soils, and their food-production requirements. Regardless of the combination of inorganic and organic fertilizers that may be used, food plants of adequate nutritional quality can be produced if existing knowledge of soil chemistry and plant and human nutrition is applied and if research programs on the nutritional quality of plants are maintained.

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Organic Matter: Its Value, Rate of Decomposition, and Source

Historically, humans have known that dark soils, commonly found in the river valleys and broad-level plains, are usually productive. They also realized, very early in their development, that color and productivity of the soils are commonly associated with organic matter derived chiefly from decaying plant materials.

Organic matter is a temporary product passing through several biological oxidation changes that eventually reduce it to carbon dioxide, water, and mineral elements. Microbiological activity is high when fresh plant residues begin to decay. As micro-organisms consume the more easily decomposable materials, the level of activity declines.

Soil organic matter of humus (that stable fraction or organic matter that remains in the soil after most plant and animal remains have decomposed) is usually divided into nonhumic and humic substances. The nonhumic substances are the compounds that are the chief constituents of higher plants, animals, and micro-organisms, such as proteins, carbohydrates, lignins, fats, waxes, resins, pigments, tannins, and certain compounds of low molecular weight. These compounds constitute the energy-supplying food of soil micro-organisms. The compounds not readily utilized by organisms, and parts of the micro-organisms themselves, remain in the soil and serve as materials for humus formation.

Humic substances are usually described as acidic, high-molecular weight substances that are yellow, brown, or black. Humic acids are produced in soils and compost piles, primarily through biological action followed, or accompanied by, chemical reactions. There is no sharp line of demarcation between nonhumic

and humic substances. Both are present at all times in all soils, and nonhumic substances are being constantly decomposed into humic ones.

Organic matter is a source of plant nutrients, particularly nitrogen, phosphorus, and sulfur. However, primary functions of organic matter are those relating to improving physical properties of soils. Organic matter will improve heavy clay soils and light sandy soils. A heavy clay soil is difficult to work, slow to absorb water, and tends to puddle so that rainfall or irrigation water will runoff rather than soak in. Organic matter makes heavy clay soils more friable and promotes a crumbly structure so that the soil absorbs water more rapidly, resulting in less runoff and erosion.

Light sandy soils will not hold water or nutrients. Addition of organic matter improves the water-holding capacity of such soils and enhances the nutrient supply. Also, nutrients are less susceptible to leaching because the organic matter will absorb them.

The level of organic matter that can be maintained economically in a soil depends on the texture of the soil, the way the soil is managed, and the climate. Maximum amounts of organic matter can be maintained in cultivated soils by maintaining vegetative cover on the land whenever possible, following good soil-management practies to produce high yields of crops, returning all residues to the soil, cultivating no more than necessary, and controlling wind and water erosion.

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Rock Phosphate

Phosphorus (P) is present in all living tissue. It is particularly concentrated in the younger parts of the plant and in the flowers and seed. Phosphorus is necessary for such life processes as photosynthesis, the synthesis and breakdown of carbohydrates, and the transfer of energy within the plant. It is a major part of the nucleus of the cell and is present in the cytoplasm, where it is involved in the organization of cells and the transfer of hereditary characteristics.

Growth is arrested when the supply of P in the soil is too low, and P from the older tissues moves to the younger tissues. Usually, therefore, signs of too little P appear first in the lower leaves, which are the older ones. The symptoms in some plants may be purple or deep red leaves. Roots are often stunted and poorly branched. A deficiency of P may delay maturity of the plant.

When P fertilizers are added to soils deficient in available forms of this element, yields of crops and pastures usually increase. Sometimes the P concentration in the crop increases and this may help to prevent P deficiency in the animals eating this crop. Some soils convert P added in fertilizers to forms that are not available to plants. On these soils, very heavy applications of P fertilizer may be required to obtain increased crop yields and little increased concentration of P in the crop is obtained. Some plants always contain low concentrations of P regardless of the P content of the soil on which they are grown.

Untreated rock phosphate is sometimes used on very acidic soils. It is also used by growers who choose not to use chemically treated solid additives. The effectiveness of raw rock phosphate for correcting P deficiencies in soil is limited by its low phosphorus content and the low solubility or availability of the phosphorus for plant use. For example, ordinary superphosphate contains 20 percent P_2O_5; triple superphosphate, 45 percent P_2O_5; monoammonium phosphate, 48 percent P_2O_5; and diammonium phosphate, 46 percent P_2O_5, as compared with untreated rock phosphate which contains less than 15 percent P_2O_5 and is insoluble. The acid used in the process of upgrading raw rock phosphate to superphosphates is neutralized so that the fertilizer results in very little residual acidity when applied to the soil.

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Sewage Sludge and Wastewater Effluents

For many years, sewage sludge and effluents have been spread on land as a means of disposal and to utilize the nutrients in the waste. Prussia was irrigating land with sewage as long ago as 1559. Sewage effluents have been applied for over 50 years at several sites in the United States. Since 1972 there has been renewed interest in land application of sewage sludge and effluent as an alternative to conventional methods of disposal. There are diverse reasons for the renewed interest in using waste on land, including the philosophy that we can overcome our energy shortages by recycling all available material; concern for the environment; and legislation like the Water Pollution Act, the Clean Air Act, and the Ocean Dumping Act. The cheapest methods of sludge disposal, fresh and salt water dilution, are no longer acceptable.

The major methods of sludge disposal used today are landfilling, landspreads, incinerating, and ocean dumping. In 1972 an estimated 40 percent of the sludge generated in the United States went into landfills; 20 percent was spread on land; 25 percent was incinerated; and 15 percent was dumped in the ocean. If ocean dumping is banned and production of sludge increases as predicted, another 170,000 tons of sludge, an 80-percent increase in the current amount, will have to be disposed of each year by acceptable means.

It is estimated that all the sewage sludge generated in the United States could supply 2.5 percent of nitrogen (N), 6 percent of phosphorus (P), and 0.5 percent of the potassium (K) sold as commercial fertilizer in 1973. Some of the available sludge cannot be used on agricultural land because of its high levels of heavy metals that may be toxic and may increase the concentration of heavy metals in edible crops.

Disposal of sewage sludge and effluents on land is a viable alternative to conventional disposal means. The waste, however, must be constantly monitored to ensure that there is no buildup of toxic elements in the environment that could be harmful to human beings or animals.

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Soil Conditioners, Activators, Inoculants, and Other Unconventional Soil Additives

With the recent increase in cost of commercial fertilizer, many products are being introduced that are claimed to be viable alternatives to commercial fertilizers. Often these products are said to have valuable properties in addition to basic fertilizer elements. These properties may be (1) minor or trace elements; (2) organic matter; (3) special bacterial cultures that increase fertilizer or improve soil structure; and/or (4) soil-conditioning ingredients. The claims for the product may or may not be valid. Even when claims are valid, they are rarely properly documented. Products advertised and sold as fertilizers are regulated by the States in which they are sold. Generally, they are required to carry a guaranteed analysis of available nitrogen, phosphoric pentoxide, and potash.

The Department frequently receives letters of inquiry about the usefulness of trade-named organic products sold for soil or crop improvement. Sometimes the Department is asked to conduct trials with these products or to perform chemical analyses on them.

The Department cannot evaluate all these specific materials. They are often variable in composition, prepared by confidential processes, contain assorted microbial cultures, or are recommended for specific uses. Characteristically, their beneficial effect on crops or soils is documented only by grower testimonials and not by objective research. Occasionally, if the Department accepts a sample of a product for trial, the producer will use this in advertising as "tested by the U.S. Department of Agriculture," or similar statement.

Organic matter is valuable in maintaining soil structure and fertility. The main difference in organic material is their decomposability. Peat, for example is well stabilized and will last for a long time. Manures, crop residue, and sewage sludge, on the other hand, are more easily decomposed, leaving only a small resistant residual fraction. Claims for unique properties of specific organic matter sources should be viewed with skepticism.

Special bacterial cultures have been tested time and again for beneficial use in soil. The only inoculation scheme that has stood the test of time is using rhizobium cultures to inoculate legumes. Even here, inoculation is probably used far more often than necessary. Special inoculants for composting, or cultures claimed to improve soil aggregation, are particularly popular. Little scientific evidence supports this concept. Microbial populations in soil or compost material rise and fall rapidly in response to the food supply. Only rarely is the initial level of microbial population so low that artificial inoculation can induce a more rapid response.

Soil conditioners are substances that cause increased aggregation of soil particles or promote stability of aggregates. Some organic compounds may have this property, but usually, to be effective, they have to be used at uneconomically high rates.

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Soil Micro-organisms

A teaspoonful of soil may contain billions of living organisms. Crop growth, soil fertility, and even soil development depend in many ways on these organisms.

Among the soil's inhabitants are specialists that rot organic matter, transform nitrogen, build soil tilth, produce antibiotics, and otherwise affect plant welfare.

Bacteria are the smallest, about 25,000 measure an inch, and the most numerous of the free-living organisms in the soil. Despite their minute size, their total weight in the top foot of an acre of fertile soil may be as much as 1,000 pounds, or 0.03 percent of the weight of the soil. Poor soils and some sandy soils may harbor few bacteria.

Only a limited number of micro-organisms are able to make use of nitrogen gas as it commonly occurs in the air. The legume-nodule bacteria, or rhizobia, for example, use nitrogen from the air in partnership with leguminous host plants. The nitrogen taken from the atmosphere is available to both partners. Consequently, legumes can be grown on soil that is poor in nitrogen but otherwise favorable. The amount of nitrogen fixed by nodulated legumes varies greatly, averaging about 50 to 150 pounds of nitrogen an acre each year.

Actinomycetes are microscopic organisms that resemble the bacteria. As a group they are important in the decomposition and the humification of organic residues. One species causes potato scab. Other species produce antibiotic substances, which have great medicinal value for humans.

Fungi exist in the soil in many different forms. Some are large like mushrooms; others are microscopic, like yeasts and molds. They have no green pigment--chlorophyll--and therefore must feed on organic materials. Many species are parasitic on plants and animals. Nonparasitic species attack a variety of substances in the soil, including such complex plant materials as cellulose and lignin. Fungi are important in decay because they can initiate decomposition and because they grow vigorously once they have gained a foothold. They can attack organic residues on the surface of the ground, as well as stored agricultural products and household items, whose moisture contents are too low to permit bacterial invasion. When air circulation is good, fungi rapidly convert organic wastes into cell substance and to carbon dioxide and water.

The bacteria, actinomycetes, and fungi are agents of decay. Collectively they are indispensable in the mineralization of plant and animal residues. These microbes have an essential part in the carbon cycle in which carbon that has been combined photosynthetically by plants is again set free as carbon dioxide by respiration and decay.

Microbes also affect the availability of various minerals in their inorganic combinations. Iron, manganese, and sulfur are transformed from unavailable to available forms by microbial oxidations and reductions. Products of microbial oxidation exert solution effects upon soil parent material and on insoluble forms of fertilizer. When rock phosphate is composted with sulfur and manure, the sulfuric acid formed by biological oxidation makes the insoluble phosphate available. Plants may get more phosphate from poorly soluble phosphate materials when they are grown in the presence of microbes than when they are grown under sterile conditions. Sulfur applied to soils as a corrective for

excessive sodium salinity is ineffective until it has been oxidized to sulfate by the soil flora. Not all activities of the soil microflora, however, are beneficial to the growth of crops. The mineral nutrients the microbes need for growth and activity are the same as those required by the higher plants. If a mineral is scarce and the supply of available energy material is abundant, the soil organisms are extremely able competitors for the scarce nutrients.

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